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Application of effective concrete composites to increase radiation protection of residential areas

V S Rudnov¹, V A Belyakov¹

¹Ural Federal University, 19 Mira street, Yekaterinburg 620002, Russia

E-mail: v.s.rudnov@urfu.ru, belyakow@rambler.ru

Abstract. The scientific article presents the analysis of studies of radiation safety of residential buildings in the city of Yekaterinburg, Sverdlovsk region and the results of the development of new building materials with protective properties. The review of available statistical data on the specified subject is carried out. It is revealed that the most simple and economically justified method of increasing the protection of the population from the radiation impact of man-made or natural environment is the construction of buildings with the use of innovative building materials or reconstruction of existing ones with the use of heavy concrete with effective radiation-protective aggregates.

1. Introduction

Currently, on the entire surface of the Earth, including the territory of residence of people can meet both small areas and significant areas in which there is an increased radiation background. The causes of this phenomenon are often natural and may be associated with the release of radioactive groundwater, zones of geological faults or halos scattering of radioactive and rare metal deposits. The most common natural source of radioactive radiation is radon gas, which together with its radioactive decay products make the main contribution to the natural radiation background of residential areas, which is about 1 mSv per year when inhaled into the human body.

However, in the residential areas of modern megacities are increasingly hotbeds of such phenomena of man-made origin, due to the progressive global transition of mankind to the use of nuclear energy and the expansion of applications of nuclear fusion. It is possible that at the end of the XXI century in each apartment in the kitchen will be a compact household nuclear power plant to provide electricity and heat needs of residents of one apartment. That is why the problem of protecting the population and the environment from dangerous neutron and γ -radiation arising in the process of nuclear fission is becoming increasingly important.

2. Results and discussion

The team of authors of the Institute of new materials and technologies of the Ural Federal University named after the first President of Russia B. N. Yeltsin studied building materials for protection against potential radioactive danger, which can be made on the basis of local raw materials of the Ural region [1-3].

The studies of the potential danger of the territory of Yekaterinburg conducted earlier by ecologists do not always correlate with each other. Yekaterinburg is a 1.5-million-strong metropolis located in the center of the mining and industrial region of the Urals – the Central part of the Russian Federation.



The radiation background of the residential area of the Yekaterinburg agglomeration is influenced by the South Ural radioactive trace, the close location of the Beloyarsk nuclear power plant and other industrial facilities. A number of authors believe that about half of the territory of Yekaterinburg has an increased background radiation mainly due to radon, which is further superimposed on local areas of man-made radioactive contamination [4-6]. Other authors note a slightly increased radon approximately uniform background throughout the metropolis. Also, in different years, epidemiological studies have been conducted to determine the dependence of lung cancer incidence and radiation due to inhalation of radon in the human body, but without proper systematization and without taking into account a significant number of other harmful factors that have carcinogenic effects [7-9].

In the process of nuclear decay, particles with different penetration into other substances are formed: neutrons, electrons, protons, fragments of heavy nuclei, mesons, α -particles and γ -radiation quanta. Charged particles (e.g. α -particles or electrons) are relatively quickly inhibited by matter. Therefore, the main danger for biological beings and humans are neutral particles (neutrons and γ -radiation), which are taken into account in the calculation of biological protection.

The interaction of these types of radiation is the ionization of the latter. In this case, there are special chemical processes that lead to disruption of biochemical processes in cells with the formation of physiological pathological changes. From the point of view of the state of the whole body, more dangerous General radiation. Sensitivity to tissue radiation in the body is different, as well as the sensitivity of individuals. When inhalation enters the human body, the lungs are most likely to suffer, in other cases, the neural tissues of the bone and brain are most exposed to radiation.

In world practice, it is generally accepted that the most optimal material for protection against most types of ion radiation is superheavy concrete, containing in its structure aggregates from a number of rocks, which is the basis for effective protection, including as part of the complex element [10].

For γ -radiation is characterized by the law of attenuation of the flow passing through the substance, which is that with an increase in the thickness of the layer of matter, the intensity of the transmitted radiation decreases in inverse proportion to the thickness of the layer under study. For the characterization of radiation protection it is common to make the thickness of the layer of the substance, in passing through which the intensity of radiation is reduced in two times. Accordingly, increasing the thickness two times, will receive a reduction of radiation intensity by 4 times, and so on. Based on this characteristic (taking into account some other factors), the thickness of the protective fence necessary to attenuate the radiation to the permissible intensity norms is calculated. The thickness of the half-attenuation layer depends directly on the density of the substance (for Portland cement concretes to a greater extent on the filler): the heavier the material, the smaller the required thickness of the fence.

Neutron radiation has a different nature and to weaken it in the structure of the material must be present chemical elements with a small atomic mass, for example, hydrogen. Concrete as a material is the most effective material for protection against these radiation, because only it can combine two types of protection against two types of radiation (fillers reduce γ -radiation, and hydrates slow neutrons). In this case, the cost remains at a relatively low level compared to the single-layer protection of heavy metal (such as lead), as well as a complex multi-layer. To obtain extra-heavy concrete is most effective use of such rocks of high density and with a significant content in the structure of chemically bound water as limonite, serpentinite and others. It is also possible to use artificial aggregates – waste metallurgy: metal scrap, lead shot, etc.

As a binder, Portland cement and its varieties are most often used, but the use of alumina and gypsum alumina cements, when hardening binding more than Portland cement, the amount of water in the crystal hydrates of tumors is also very justified for increasing neutron protection. To further improve the protective properties of the concrete is also introduced additives containing light elements such as carbide, boron, lithium chloride and others.

There are different opinions on the contribution of components to the operational, including radiation-protective properties of concrete. Such scientists as A. P. Veselkin, E. V. Voskresensky, V.

A. Egorov and other researchers believe that the protective properties are determined by fillers. Other scientists, for example V. P. Mashkovich, A. V. Kudryavtseva, B. N. Vinogradov, believe otherwise and emphasize that the type of binder has a significant impact on the protective characteristics of concrete. Therefore, when designing new protective composites, it is necessary to take into account the chemical and physical characteristics of all components [11,12].

The size of aggregates for protective concretes is recommended to determine the massiveness of the concreted structure and choose the largest, and the particle size composition should be chosen so that the content of aggregates in the structure of concrete was as much as possible. In this case, the density of such concrete will increase, and the thickness required for protection will decrease. This is possible with the use of intermittent grain aggregates, as well as the use of three fractions.

The authors conducted research in the laboratory of the Institute of new materials and technologies of the Ural Federal University named after the first President of Russia B. N. Yeltsin. As the object of study were selected rocks, which presumably have the structure of the crystal lattice to retain ionizing radiation. Two types of inert materials were obtained from rock samples: crushed stone of 10-20 mm fraction and sand from crushing screenings. With the help of a binder Portland cement were made samples of concrete, in which a large aggregate is made of the test rock, and in the second case – a small aggregate (table.1).

Table 1. Variants of combination of types of aggregates for protective concrete

Number of sample's	Coarse aggregate	Fine aggregate
1	barite	granite
2	magnetite	granite
3	hematite	granite
4	limonite	granite
5	dunite	granite
6	granite	barite
7	granite	magnetite
8	granite	hematite
9	granite	limonite
10	granite	dunite

Currently, many authors have investigated the inhibition of fast monoenergetic neutrons, which simplifies the understanding of the physical nature of the neutron deceleration and is used in the calculation of protection against this type of impact. The spatial-energy distribution of γ -quantum fluxes in media is described by the transport equation, for which it is difficult to find an exact solution. In this regard, it has recently become accepted to be based on empirical dependences obtained as a result of experiments with radiation sources.

After hardening of the samples under normal conditions up to 28 days, the samples were examined to determine their radiation-protective properties. Studied rocks: barite, magnetite, hematite, limonite and dunite. In the course of experiments, the degree of radiation absorption by concrete samples (in % of the intensity without samples) was determined using a dosimeter with a remote unit (scintillation gamma dosimeter). Isotopic sources were used in experiments to obtain γ -radiation. The studied concrete samples were placed directly in front of the detector at a distance of 420 mm to fix the dose rate of $\mu\text{sv/h}$ radiation obtained in 60 seconds. In the study of the degree of absorption of neutron radiation, the source was a Pu-Be fast neutron reactor with an energy of up to 12 MeV. The distance to the sample and the irradiation time were the same. The results of determining the dependence of the degree of absorption of γ -radiation on the type of rock and (crushed stone on the right, sand – on the left) are shown in figure 1.

Then the degree of neutron radiation absorption from the same parameters (Figure 2).

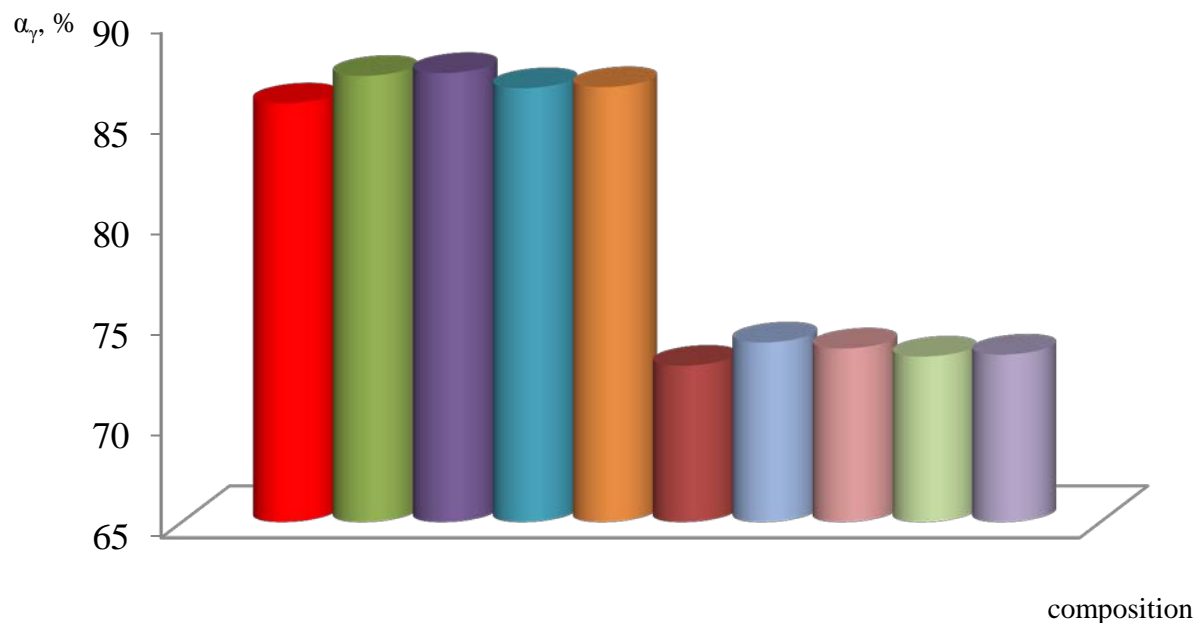


Figure 1. The dependence of the degree of absorption of γ -radiation from the type of filler.

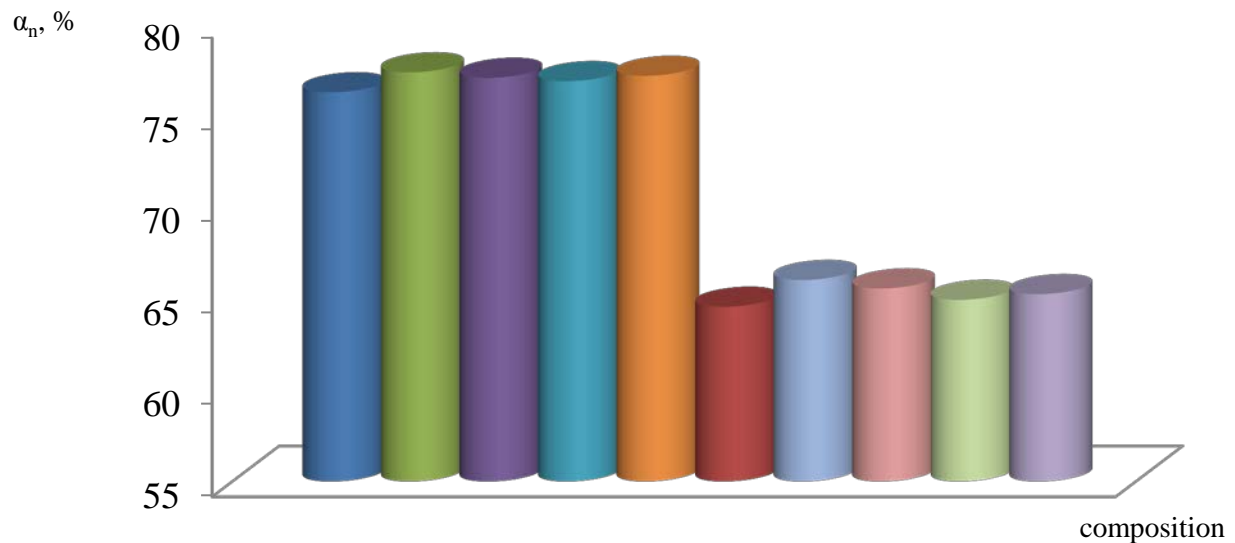


Figure 2. The dependence of the degree of neutron radiation absorption on the type of filler.

3. Conclusion

As a result of the research we can draw conclusions:

- the most effective use of rocks as a large aggregate, because the grinding is destroyed part of the crystallization bonds;
- the studied rocks have comparable efficiency in terms of protection against radiation, which is shown in the study of gravel and sand and does not depend on the size of the material used;

- it is recommended to develop maps of residential areas with an indication of increased radiation hazard and during the reconstruction of buildings in high-risk centers, to work with the use of radiation-protective concrete.
- in areas with high radon content it is recommended to use effective radiation-protective concretes for the construction of basements and basement structures of residential buildings, which will significantly reduce the impact of the main factor of natural origin;
- new construction of buildings or parts thereof that require increased protection against ionizing exposure, the use of concretes with large aggregates of recommended rocks;
- the size of the fillers for the protective concrete is recommended to be taken as much as possible in order to reduce the thickness of the half attenuation.

References

- [1] Khoroshavin L B, Medvedev O A and Belyakov V A 2014 Tecnologia smaltimento dei rifiuti radioattivi (RRA) *Italian science review* **10** 175-179
- [2] Belyakov V A, Rudnov V S and Akhtyamova V A 2016 Application of Dunite Aggregates to Increase Radiation-Protective Properties of Heavy Concretes *Science and Business: Ways of Development* **12** 46-49
- [3] Noskov A S, Rudnov V S and Belyakov V A 2014 Research and development of rational compositions effective for radiation-shielding concrete *Concrete technologies* **10** 20-23
- [4] Nikolaev A V 1961 Protection against radioactive radiation (Moscow: Metallurgizdat) p 420
- [5] Batlutskaya I V, Bolkhovitina E A, Malanina O A and Khorolskaya E I 2010 Assessment of the environment using information of important indicators of the type of bioindicator *Scientific sheets. Series Natural Sciences* **9** 80-85
- [6] Grachev V A 2008 Essays on the ecology of the industrial districts of the Sverdlovsk region Uncomfortable zone habitats of the population of the Middle Ural
- [7] Koltover V K 1994 Radiological problem of radon *Radiation biology. Radioecology* Vol. **34** (2) 257-264
- [8] Pocecun V A, Rudnov V S and Shepel S V 2014 Radioactive safety of residential areas on the example of Yekaterinburg *Ecological safety of mining regions: Proceedings of the II International scientific-practical conference* 156-159
- [9] Yarmoshenko I V, Onishchenko D A and Zhukovsky M V 2009 A survey of the levels of accumulation of radon in residential buildings in the city of Yekaterinburg (Yekaterinburg: Institute of industrial ecology) pp 62-69
- [10] Korolev E V, Samoshin A P, Smirnov V A, Korolev O V and Grishina A N 2009 Methods and algorithm of synthesis of radiation-protective materials of new generation (Penza: PGWC) p 130
- [11] Dvorkin L I and Dvorkin O L 2012 Special concretes (Moscow: Infra-Engineering) p 368
- [12] Ruengsri S 2014 Radiation shielding properties comparison of Pb-based silicate, borate and phosphate glass matrices *Science and Technology of Nuclear Installations* **2014** 218-241